
FOREWORD

This primer is intended for people interested in DOE environmental problems and in their potential solutions. It will specifically look at some of the more hazardous metal and radionuclide contaminants found on DOE lands and at the possibilities for using bioremediation technology to clean up these contaminants.¹

Bioremediation is a technology that can be used to reduce, eliminate, or contain hazardous waste. Over the past two decades, it has become widely accepted that microorganisms, and to a lesser extent plants, can transform and degrade many types of contaminants. These transformation and degradation processes vary, depending on physical environment, microbial communities, and nature of contaminant. This technology includes intrinsic bioremediation, which relies on naturally occurring processes, and accelerated bioremediation, which enhances microbial degradation or transformation through inoculation with microorganisms (bioaugmentation) or the addition of nutrients (biostimulation).

Over the past few years, interest in bioremediation has increased. It has become clear that many organic contaminants such as hydrocarbon fuels can be degraded to relatively harmless products like CO₂ (the end result of the degradation process). Waste water managers and scientists have also found that microorganisms can interact with metals and convert them from one chemical form to another. Laboratory tests and ex situ bioremediation applications have shown that microorganisms can change the valence, or oxidation state, of some heavy metals (e.g., chromium and mercury) and radionuclides (e.g., uranium) by using them as electron donors or acceptors. In some cases, the solubility of the altered species increases, increasing the mobility of the contaminant and allowing it to more easily be flushed from the environment. In other cases, the opposite will occur, and the contaminant will be immobilized in situ, e.g., precipitated into an insoluble salt in the sediment. Both of these kinds of transformations present opportunities for bioremediation of metals and radionuclides —

either to lock them in place, or to accelerate their removal. DOE's goal is to reduce the risk of groundwater, sediment, and soil contamination at Department of Energy facilities.

Subsurface bioremediation of metals and radionuclides at the site of contamination (in situ bioremediation), particularly of contaminants found in mixed waste, is not yet in widespread use. However, successful in situ applications of bioremediation to petroleum products and chlorinated solvents provide experience from which scientists can draw. Taken together, the accomplishments in these areas have led scientists and engineers to be optimistic about applying this technology to the mixtures of metals and radionuclides that are found at some of the most contaminated DOE sites.

This primer examines some of the basic microbial and chemical processes that are a part of bioremediation, specifically the bioremediation of metals and radionuclides. The primer is divided into six sections, with the information in each building on that of the previous. The sections include features that highlight topics of interest and provide background information on specific biological and chemical processes and reactions.

The first section briefly examines the scope of the contamination problem at DOE facilities. The second section gives a summary of some of the most commonly used bioremediation technologies, including successful in situ and ex situ techniques. The third discusses chemical and physical properties of metals and radionuclides found in contaminant mixtures at DOE sites, including solubility and the most common oxidation states in which these materials are found. The fourth section is an overview of the basic microbial processes that occur in bioremediation. The fifth section looks at specific in situ bioremediation processes that can be used on these contaminant mixtures. The primer concludes with a hypothetical case study of a composite DOE site with polluted groundwater containing some of the Department of Energy's most recalcitrant contaminants.

1. DOE's Office of Science has a bioremediation research program entitled Natural and Accelerated Bioremediation Research (NABIR). NABIR is responsible for the development of this primer. NABIR focuses on the in situ bioremediation of metals and radionuclides in the subsurface below the root zone. However, this primer discusses a broader range of remediation technologies than the program supports, giving its readers an overall context for bioremediation technology.